STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

DYNAMIC FULL SCALE IMPACT TESTS OF CABLE TYPE MEDIAN BARRIERS TEST SERIES VII

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State of California
Highway Transportation Agency
Department of Public Works
Division of Highways
Materials and Research Department

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Mr. James E. Wilson
Traffic Engineer
California Division of Highways
Sacramento, California

Dear Sir:

Submitted for your consideration is a report of:

DYNAMIC FULL SCALE IMPACT TESTS

of

CABLE TYPE MEDIAN BARRIERS

TEST SERIES VII

Study made by . . . . Structural Materials Section
Under the direction of . . . . E. F. Nordlin
Project Engineer . . . . R. N. Field
Photographic Instrumentation . . . . R. M. Souza
Report prepared by . . . . R. N. Field

Very truly yours,

JOHN L. BEATON
Materials and Research Engineer

EFN/RNF:mw
cc: Hdqtrs. Depts.
Traffic Dept. (25)
District Engineers
Urban Planning (8)

DYNAMIC FULL SCALE TESTS OF CABLE TYPE MEDIAN BARRIERS

SYNOPSIS

During the spring of 1963 four full scale dynamic impact tests were made on three designs of cable type barriers. One of the four tests was made on the current standard design for the purpose of correlating with tests made during the 1961 test series (Reference 1) and three tests were made on modifications of our present cable barrier design.

The design modifications consisted of (1) deletion of the mesh from the system and (2) reduction of the post height from the standard 58 inches to 39 inches above the ground.

The impact angle for each of the four tests was 25 degrees oblique to the barrier at speeds ranging from 83 to 90 miles per hour. The same test site and cable installation was used for all four of the tests. For each successive test, the damaged posts were replaced with new posts installed in the original socketed footings. The only major repair required was the repouring of the end anchor after it was jerked from the ground during Test No. 2. (The failure of the end anchor due to faulty construction voided Test No. 2, as the vehicle reaction was adversely affected by the sudden release of tension on the cable.)

This report describes the test procedures and results based on data secured from the four high speed oblique angle impacts on three cable-barrier designs.

Radio control techniques and photographic instrumentation used for this test series were identical to those used in previous barrier test series. For a thorough discussion and full details on these features of the test program, see References 1 and 2.

This study was conducted in cooperation with the Bureau of Public Roads.

I. BACKGROUND AND HISTORY

Since the inception and first trial installation of cable-chain link median barriers were made on the Nimitz and Santa Ana freeways in 1959, there have been more than 100 miles of cable type barrier constructed and in operation on California's freeways.

The first trial design (Exhibit 1) was proof tested before installation on the freeways by means of six controlled vehicle impacts conducted at speeds of from 45 to 60 miles per hour. The forementioned six tests were a portion of the 1959 median barrier impact test series and are reported in the January 1960 Highway Research Board Proceedings (Reference 2).

Minor deficiencies affecting the cost of maintenance of the original three-cable design were noted after less than one year's operational experience. A second test series was initiated early in 1961 to determine what improvements could be made to the existing cable barrier design that would contribute to a reduction in the costly maintenance of this barrier. This series of nine additional dynamic impact tests was conducted primarily to observe the effect that various maintenance improvements would have on the over-all effectiveness of the cable-type barrier under dynamic impact conditions. The results of this 1961 impact series on cable-type barriers along with a performance analysis based on one year's operational experience were reported in 1962 (Reference 1). (See Exhibit 2 for details of the cable barrier as revised in 1961 after this second test series.)

The following tabulation is a resumé of the most important test parameters and observations from the first fifteen full scale impact tests (Series V and VI).

Test	Angle Deg.	Vehicle	Speed mph	Cables	Mesh On	Deflection	Damage	Performance
512	27	52 Ford	56	1 @ 9" 1 @ 27"	Woven in and out	7' 2"	50 ft.	150 deg. spin out
514	31	53 Chev	61	1 @ 9" 2 @ 30"	Impact side under cable	8' 6"	80 ft.	Smooth decel.
519	15	53 Chev	41	1 @ 9" 2 @ 30"	Opposite under cable	3' 4"	35 ft.	Smooth decel.
520	32	54 Chev	52	1 @ 9" 2 @ 30"	Impact side under cable	9' 0"	24 ft.	Cartwheeled
521	31	53 Chev	60	1 @ 9" 2 @ 30"	Impact side under cable	8' 0"	56 ft.	Smooth decel.
523	34	37 bus	42	1 @ 9" 2 @ 30"	Opposite under cable	12' 0"	90 ft.	Smooth decel.
61	7	59 Dodge	78	1 @ 9" 2 @ 30"	Impact side under cable	5' 6"	152 ft.	Violent 180° spin-out
62	7	59 Dodge	84	2 @ 30"	do	5' 6"	140 ft.	Violent 280° spin-out
63	7	59 Dodge	86	2 @ 30"	do	6' 0"	152 ft.	Violent 300° spin-out
64	10	59 Dodge	76	2 @ 30"	Opposite under cable	6' 0"	136 ft.	Violent 270° spin-out
65	7	59 Dodge	84	2 @ 30"	Impact side not under cable	7' 0"	112 ft.	Violent 250° spin-out
66	7	59 Dodge	75	2 @ 30"	do	6' 0"	136 ft.	160° spin-out
67	7	59 Dodge	77	1 @ 20" 1 @ 32" 1 @ 44"	do	5' 6"	184 ft.	Climbed 2 bottom cables
68	22	59 Dodge	74	2 @ 30" on 8 % ramp	do	vehicle jumped	35 ft.	Vehicle cleared Barrier
69	20	59 Dodge	82	1 @ 30" envelope on 8 % ramp	do	12' 0"	136 ft.	180° spin-out

This is a report on Series VII, a third series of cable-type barrier tests consisting of four dynamic impacts which were recommended by the Traffic and Planning Departments in the fall of 1962 for the purpose of determining the effect that the deletion of the chain link mesh would have on the operational efficiency of the cable barrier. It was suggested that the mesh be deleted when existing center line plantings conflicted with the barrier erection, or when future plantings were planned for the center of an unpaved median.

The four tests reported herein bring the number of dynamic impact tests to a total of 19 conducted by the State of California on cable-type median barriers.

II. OBJECTIVES

The basic objectives of the 1963 Series VII cable barrier impact tests were as follows:

1. To observe the effect of deletion of the chain link mesh from the system while retaining the original 58 inch post height.

2. To observe the effect of deletion of the chain link mesh and shortening the posts from a height of 58 inches to 39 inches minimum above the ground or at least 12 inches above the cables.

3. To determine the operational efficiency of a new pipe type turnbuckle design with swaged cable pulls. (See Exhibit 3-C.)

4. To determine the retention efficiency of the end anchor as presently designed when subjected to the severe loading of an 83 to 90 mph impact.

5. To determine the effect of decreasing the height of the cables from the 30 inch height as used for 14 of the 15 previous tests to the 27 inch minimum height as specified on the subsequent Standard Plan A76-4 (Exhibit 4).

6. In addition to the 5 basic objectives, it was also possible to observe the efficiency of a preformed cable splice under severe impact conditions.

III. CONCLUSIONS

From an analysis of the data resulting from the four full scale collision tests, the following conclusions were made:

1. The effectiveness of the cable type barrier in retaining a high speed impacting vehicle is not materially affected by (1) deletion of the chain link mesh from the system, (2) decreasing the post height from 58 to a minimum of 39 inches or at least 12 inches over the cables, or (3) a combination of both deletion of the mesh and reduction of post height. However, it should be pointed out that the chain link mesh does offer some protection to the motorist from opposing headlight glare. It is also probable that the chain link mesh provides a psychological assurance to some motorists that a positive barrier does in fact exist. Therefore, should the chain link mesh be deleted, particularly on a narrow median, some type of screening material could be substituted for the mesh. This screening may be in the form of plantings, expanded metal or other metallic or plastic materials.

2. The pipe-type turnbuckle with swaged cable pulls was proven to be as strong as the open type during the 1961 test series. As a result both the pipe-type and the drop-forged open-type turnbuckles were included as alternates in Standard Plan A76-2 early in 1961 (Exhibits 3-A and 3-B). The results of the 1963 test series confirm the observations made during the earlier 1961 series -- that there is no tendency for the pipe-type turnbuckle to either snag on the vehicle body or restrain the free passage of the cable clamps and chain link mesh bundle during impact. For this reason the pipe-type is now considered to be superior to the drop-forged open-type turnbuckle.

3. End anchors as designed are efficient providing the sidewalls are vertical.

4. The cable is effective at a minimum height of 27 inches. It is recommended that under field conditions, the cable be installed at 27 inches, plus 3 inches, minus 0 inches. This reduction in design height will contribute to a reduction in the number of under-the-cable type vehicle penetrations.

   Further studies are currently underway to determine the optimum cable height for each of the various median cross sections.

IV. DISCUSSION

BARRIER PENETRATION

The performance as outlined on the individual data sheets (Exhibits 13 through 16) and the test sheets (pages 12 through 15) indicates that the deletion of the chain link mesh or a reduction in post height does not adversely affect the over-all efficiency of the cable barrier. The forementioned conclusion is based primarily on the similarity in the vehicle/barrier performance and cable deflection between the control Test No. 1 and Tests No. 3 and 4 (17 ft. deflection for each of the 3 tests). In our opinion the post height is not critical provided that there is sufficient length of post above the top of the cable so that the post can bend before the cable clamp releases and strips clear of the top. It is therefore recommended that the 12 inches of post length above the cables, as tested (39 inches above the ground), be set as a minimum dimension until further tests or operational experience prove otherwise. Once the posts have sustained the initial bend and the cable clamps have released, a majority of the effective energy absorbing elements in the system have been utilized. Any further bending of the posts or stripping of the cables does not appear to contribute materially to the efficiency of the system in decelerating the vehicle. A comparison of the barrier damage incurred during Tests No. 1 and 4 also indicates that the vehicle reaction was not as expected. When the posts were shortened from 58 to 39 inches, the vehicle did not progress further along the barrier nor did it inflict more damage when the post height was reduced.

SPIN-OUT

Studies of freeway accidents involving the cable barrier indicate that vehicle spin-out is a serious problem. Ejection of the driver, passenger or both during a spin-out has been a primary contributing cause of serious injuries and fatalities resulting from high speed impact with the cable-type median barrier. The third cable placed at 9" above the ground on the original cable barrier design was an attempt to minimize spin-out by trapping the wheels of the vehicle as it crossed back over the center line during the post impact trajectory. However, operational studies made during the first year after installation of this three-cable design indicated that rather than alleviating the spin-out, the bottom cable compounded the accident problems by providing a ramp for an impacting vehicle to climb up and over the barrier. It was recommended at that time, after analyzing the results of nine additional controlled impact tests in Series VI, that the bottom cable be removed from existing installations and that the standard plans be revised to include only the two cables at a height of 30 inches above the median.

Analysis of the data from a total of 19 barrier tests in Series V, VI, and VII indicates that as the impact angle lessens, there is a marked increase in the violence of the spin-out. A close analysis of the data film shows that at narrow impact angles, (7 degrees or less) and at speeds in excess of 65 mph, the vehicle is never redirected from its original heading (see Exhibit 5-B). Rather, the vehicle tends to yaw or "crab" through the collision, violently spinning-out when the resistance of the barrier overcomes the energy remaining in the colliding vehicle (see also tabulation of previous tests on page 3).

It has been found that this violent spin-out is also a problem on wide angle impacts (25 degrees or more) when the speeds are excessively high (80 mph and over). The extreme and excessive deflections (17 ft. and over) coincidental with these high speeds permit the vehicle to tension the cables like bow strings. The restitutional forces in the system can cause the cables to flip the vehicle off the barrier rather than redirecting it on a new course parallel to the barrier (see Exhibit 5-A).

In summary, a high percentage of the serious injuries and fatalities that do occur with the cable type are the result of the forementioned violent spin-out action during impact at speeds generally in excess of 65 mph. It appears that this situation can best be alleviated by the use of seat belts to prevent ejection of occupants. In California, recent legislative action making seat belts mandatory in all 1964 models is a strong step in this direction.

POSTS

The following observation is noted here as a precaution that a dangerous situation could result from an oblique angle impact at very high speed in excess of 75 mph on the cable barrier. The posts that were stripped of the cables and bent to almost 30 degrees from the horizontal, pierced the body of the vehicle as it yawed back over the center line during the spin-out (see Exhibits 9, 11, and 12). This piercing or spearing of the vehicle body by the bent posts was evident on all three tests where the vehicle spun out, regardless of post length. It was noted that the 58 inch posts used on Test No. 1 were the only ones that penetrated through the body to the inside of the vehicle. However, the significance of this excessive penetration of the vehicle by the longer posts has not been determined. There is no evidence to date from the many hundreds of accident reports reviewed that this "spearing" of the vehicle body is in fact a hazard. There is only a very remote possibility of this occurring on the freeways.

It may be noted that in Test No. 4 (Exhibit 12-C) one of the posts was pulled from its socket. Close examination of the post socket revealed 4 inches of water in the bottom of the can. Improper drainage of the socket prior to filling it with asphalt resulted in poor adherence of the asphalt to the can. However, in construction practice, this deficiency would not be encountered. The contractor's normal procedure is to place the post in the can and fill it with asphalt prior to placement of the post/can unit in the hole for the final pouring of the concrete footing.

TURNBUCKLES

The same four pipe-type turnbuckles (Exhibit 3-C) were used for all four of the barrier tests, 2 in the impact zone and 2 at the end anchor (see Exhibit 6). The only damage sustained was three bent studs that required replacement. For each of the tests two of the turnbuckles were positioned ahead of the point of impact so that the efficiency under the following conditions could be observed: (1) breaking strength under direct loading, (2) passing of the turnbuckle assembly through the vehicle body without entrapment, and (3) passing of the stripped cable clamps over the body of the turnbuckle without jamming.

Past experience with the open type turnbuckle (Exhibit 3-B) during controlled impact tests has proven that entrapment can be a problem. Researchers at the General Motors Proving Ground (Reference 3) reported that vehicle entrapment on a turnbuckle was a serious problem, especially when a colliding vehicle contacts an open type turnbuckle that is extended its full 3 ft. length (see Exhibit 7-A and B). As shown in these exhibits, the mesh and "U" clamps have gathered on the cable and jammed at the turnbuckle. This entrapment of the mesh and "U" clamps contributed to the violent spin-out of the vehicle and subsequent heavy damage to the vehicle and anchor. Exhibit 7-B also shows the entrapment of the turnbuckle on the post by the "U" clamp. During the 1961 tests it was found that this entrapment was a serious problem and the recommendation was made that if a turnbuckle was located at or within 6" of a post, the "U" clamp should be deleted and the turnbuckle fastened to the post with tie wires.

As a result of the 1961 tests on cable barriers with pipe-type turnbuckles, the Standard Plans for cable-chain link median barriers were revised to include them as an alternate to the conventional open type turnbuckle (see Exhibit 2 for the standard design recommended and adopted in 1961).

The favorable results of the 1961 tests, along with the results of the latest four dynamic impact tests, indicate that the pipe-type turnbuckle as shown in Exhibits 3-A and 3-C should be adopted as the standard design with no alternate allowed. The 1963 tests indicate the following:

1. The pipe-type turnbuckle passes smoothly through the vehicle with no tendency to catch on any portions of the body.

2. There was no evidence of failure of either of the turnbuckles, even after 3 direct impacts at 83 to 90 mph.

3. The bent studs damaged during Tests No. 2 and 3 (Exhibits 10-B and 11-C) were easily removed and new studs replaced in a minimum of time and with a minimum of effort.

4. The stripped clamps passed freely over this smaller diameter turnbuckle minimizing the chances of snagging the vehicle on the bundle of clamps and mesh.

REPAIR SPLICES

The first application of the preformed cable splice was made during the 1961 test series where it was proven inadequate when installed as a full tension member connecting a severed cable in the system. This method of splicing cables has proven valuable and efficient when applied to statically loaded cables such as used on power pole grips and high tension electrical transmission cables. However, during a dynamic type of loading such as occurs during a vehicle impact, the exposed ends of the preformed splice rods can catch on the vehicle body as it slides along the cables. This catching can release one end of the cable from the unit much in the same manner as the Chinese finger sleeve releases the fingers when compressed from either end. However, the release during the 1961 test occurred after the vehicle had started its spin-out, otherwise the vehicle would have penetrated over the barrier. Exhibit 8-A is a post-impact view of this test showing the preformed splice still attached to one end of the cable.

Exhibits 12-A, B, and C show the damaged cable before repair, after repair with preformed splice, and after impact. Exhibit 12-A shows that the cable was not completely severed before installation of the preformed splice. For this test the preformed splice rods were used only to reinforce this damaged section. Note the frayed ends of the splice adjacent to the post in Exhibit 12-C. During this particular test, the sliding post (pulled from its socket during impact) contacted and frayed the end of the preformed splice. Had the preformed splice been acting as a full tension member rather than as a reinforcing member, the cable would have been released. It is therefore recommended that when splices are required in the tension cables, conventional 3/4 inch cable clips (Crosby Clips) be used. Exhibit 8-B shows the recommended method of making a field splice in the 3/4" tension cables. It should be noted that any splice of this type will develop only 80% of the breaking strength of the cable. Exhibits 8-C and D show the proper and improper methods of terminating a cable in a clevis. Note that in Exhibit 8-C the grip of the clip is properly placed on the "live" end of the cable. Refer to Exhibit 11-B and note that the grip of the clips was improperly placed on the "dead ends" on both cables. Note also that the clevis pin on the left hand cable had slipped, almost releasing the cable. This was a result of the cable snapping off the thimble and rolling over the pin as the cable slipped through the improperly placed clips. However, had the safety cotter pin been inserted in the clevis pin, this problem would not have developed. The recommended spacing for the cable clips is 4 inches on centers, and a minimum of four clips are required on any splice or dead end to develop the specified 80% of the cable strength.

POST FOOTINGS

Although there were 23 post footings cracked during the series, only one was considered serious enough to warrant repair or replacement. An epoxy mix was poured into the cracks of the damaged footings as an expedient to the progression of the test series rather than an experiment. After a repeat impact, it was proven that this method of repair was completely satisfactory. However, the cost was high (1 gallon epoxy mix @ $18.00). Early in 1963 (after the test site had been constructed) recommendations were made to increase the post footing diameter from 8" to 10" and upgrade the P.C.C. mix from Class B (5 sack) to Class A (6 sack). Exhibit 4 (Standard Plan A76-4) shows a detail of this post footing modification adopted in 1963 to minimize the cracking and spalling noted by the maintenance departments on our freeway barrier installations.

V. RECOMMENDATIONS

1. Line turnbuckles should be of the pipe type, with swaged cable pulls (either factory or field swaging is acceptable). The diameter of the turnbuckle body should be two inches maximum. The breaking strength of the complete unit installed on the cables should not be less than that of the tension cables (see Exhibits 3-A and C for details).

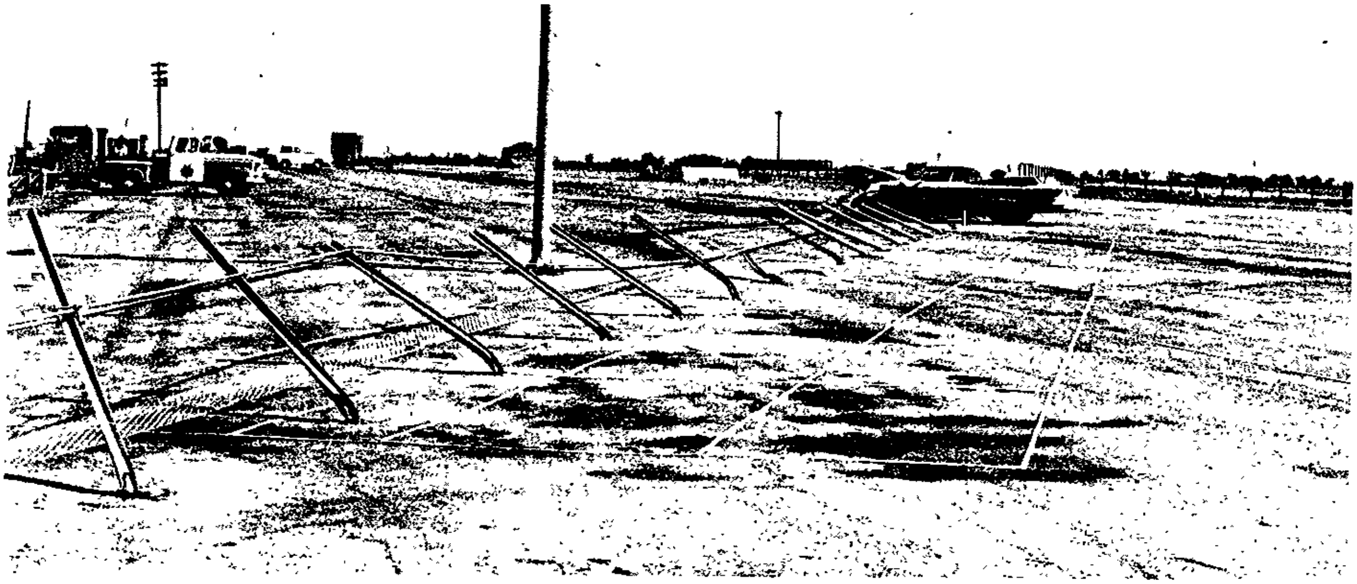
2. The tension cables should be placed no more than 30 inches nor less than 27 inches above the ground. When practical, on paved medians the cable height should be maintained as close to 27 inches as possible.

3. The mesh may be deleted from the system for the purpose of planting bushes or erecting a suitable headlight glare screen other than chain link.

4. Mesh deletion should be accompanied by a decrease in post height to a minimum of 39 inches above the ground or 12 inches above the cables, whichever is the greater.

5. As no adverse reports have been received from the field indicating that improper excavation for or placement of the end anchors have resulted in loosening or failure, no recommended changes will be made in the size or shape of the tension cable terminal anchors at this time.

6. Preformed splices should be limited to the repairing of damaged cables where there is a loss of less than 25 percent of the strands.



TEST NO. 1

FABRIC: Chain link on side opposite to impact. "U" of cable clamps on side opposite to impact. Fabric not contained by cables.

CABLES: 2 each 3/4 inch 6 X 19 IWRC @ 30" above pavement.

CABLE ANCHOR: 3' 0" long X 2' 6" wide X 1' 9" deep PCC at each end.

TENSION WIRE: One 7 gage spring steel wire 57" above pavement.

CABLE TURNBUCKLE: 1 " pipe type turnbuckle on each cable located 8 ft. and 16 ft. beyond the point of impact.

POSTS: 2¼" X 4.1# X 88" H section fence post installed with 58" above the ground line.

POST FOOTING: Type "B" sheet metal socket filled with 200-300 penetration asphalt and embedded in 8" diameter of Class B P.C.C.

PURPOSE:

1. To test the present design for correlation with previous test series (1961).

2. To test the effect of a high speed collision at 25 deg. impact angle. (Previous high speed tests were conducted at 7 to 10 deg. on flat medians.)

3. To test efficiency of the pipe type turnbuckles with swaged socket cable pulls and high strength stud inserts.

MAXIMUM ENCROACHMENT ON TRAVELLED SIDE: 8 feet.

MAXIMUM ENCROACHMENT ON OPPOSING SIDE: 17 feet.

BARRIER DAMAGE (See Exhibit 9): Anchor behind impact pulled from the ground (Exhibit 9-A), one post footing damaged beyond repair, and 25 posts bent beyond repair.

PERFORMANCE: See Exhibit 13.

All wheels remained on the pavement throughout the run. The vehicle rolled to the left and yawed slightly to the right with a very smooth deceleration. The vehicle remained embedded in the fence approximately 90 feet from impact. Application of the brakes approximately 12 feet after impact lessened the spin-out that would normally be expected. The turnbuckles passed through the vehicle body without any evidence of snagging. The cable clamps passed over the turnbuckles without jamming.

TEST NO. 2

FABRIC: None.

CABLES: 2 each 3/4 inch, 6 X 19, IWRC @ 30" above pavement.

CABLE TURNBUCKLE: 1 " pipe type on each cable, located 80 ft. and 88 ft. beyond the point of impact.

CABLE ANCHOR: Same as for Test No. 1. Anchor was replaced in the original hole and soil was backfilled and compacted.

POSTS: 2¼" X 4.1# x 88" H section fence post, installed with 58" above the ground line.

POST FOOTING: Same as for Test No. 1. The footing damaged in Test No. 1 was repaired by pouring an epoxy cement into the cracks.

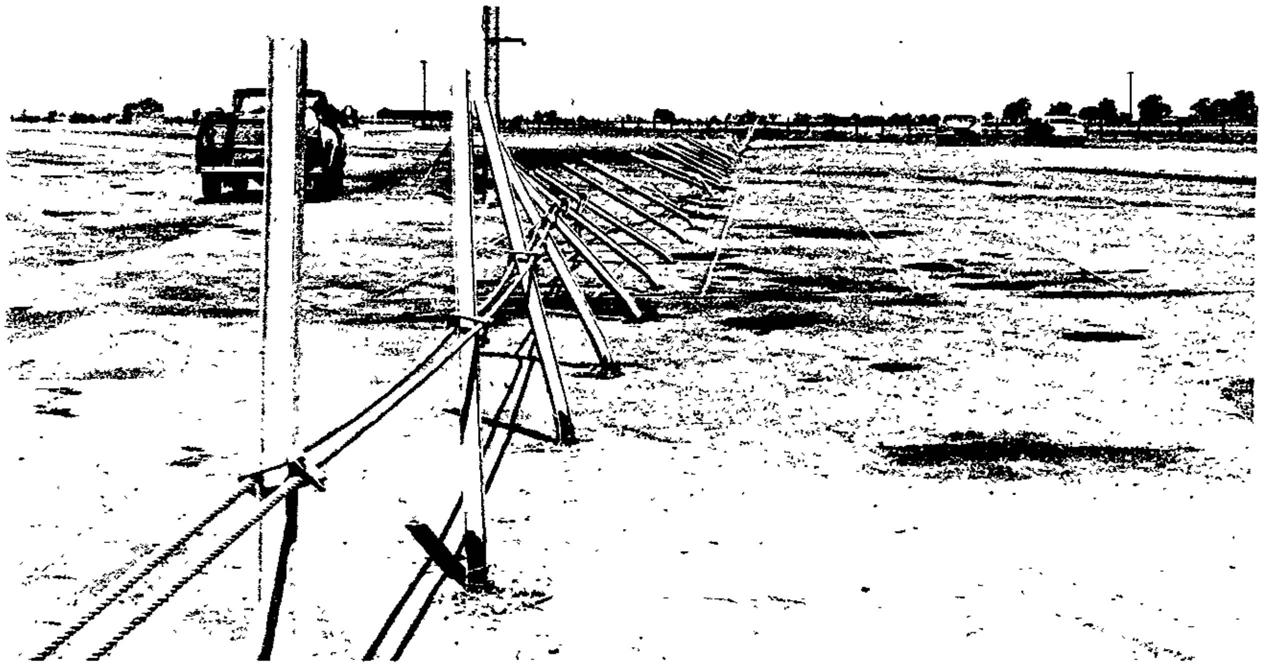
PURPOSE: To test the effectiveness of the standard cable-type barrier without the chain link fabric.

MAXIMUM ENCROACHMENT ON TRAVELLED SIDE: 0 feet.

MAXIMUM ENCROACHMENT ON OPPOSING SIDE: 72 feet.

BARRIER DAMAGE (See Exhibit 10): The rear cable anchor was jerked from the ground and rolled 56 feet toward the point of impact (Exhibit 10-D). Thirty-seven posts were bent beyond repair. The turnbuckles were bent requiring replacement of one of the studs (see Exhibit 10-B).

PERFORMANCE: See Exhibits 10 and 14. An adequate analysis of the performance of this barrier in relation to the purpose of the test cannot be made because of the failure of the anchor block approximately half way through the run. The anchor failed because the backfill material placed during the repairs after Test No. 1 was wet and not thoroughly compacted. However, all wheels remained on the pavement until the vehicle crossed over the cables and spun around approximately 300 degrees. During the spin, the left rear wheel left the pavement and the vehicle rolled to the right. The turnbuckles passed through the vehicle body with no evidence of snagging.



TEST NO. 3

FABRIC: None.

CABLES: Same as in Test No. 2.

CABLE TURNBUCKLE: Same as in Test No. 2, located 32 ft. and 40 ft. ahead of the point of impact.

CABLE ANCHOR: Anchor that failed in Test No. 2. was repoured. The sides of the excavated hole were squared-up, which increased the dimensions slightly and two posts were driven diagonally into the excavated hole for additional reinforcing.

POST FOOTING: Same as for Test No. 1.

POSTS: $2\frac{1}{4}$" X 4.1# X 88" H section fence post, installed with 58" above the ground line.

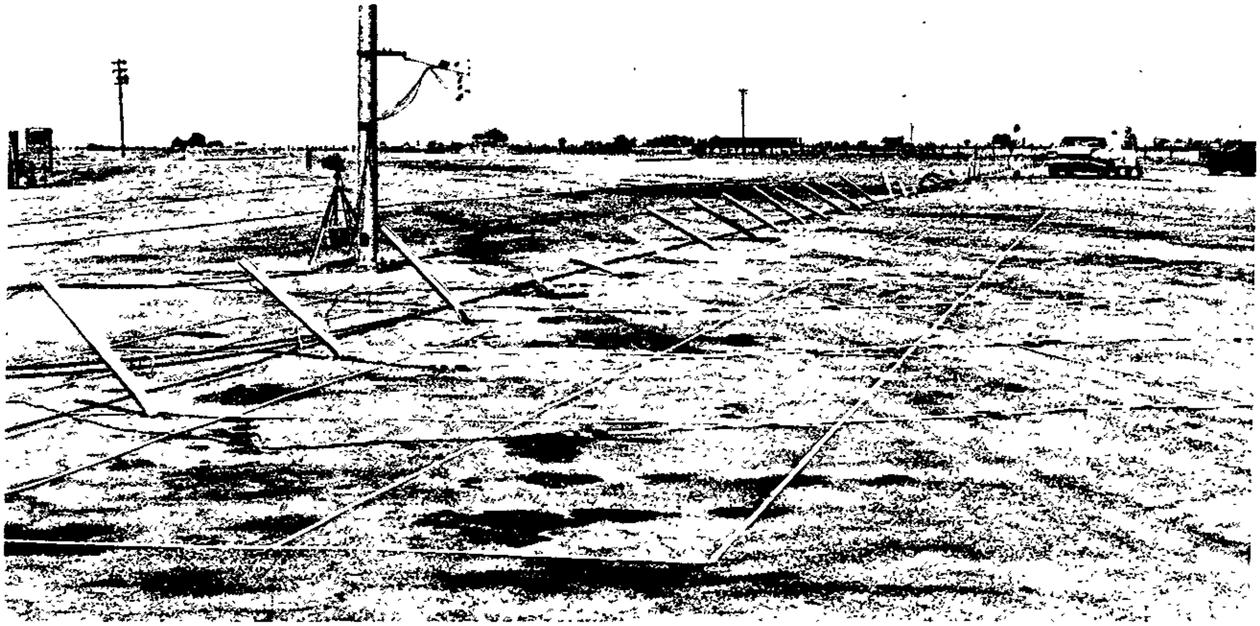
PURPOSE: This was a repeat of Test No. 2.

MAXIMUM ENCROACHMENT ON TRAVELLED SIDE: 36 feet.

MAXIMUM ENCROACHMENT ON OPPOSING SIDE: 17 feet.

BARRIER DAMAGE (see Exhibit 11): 29 posts bent beyond repair. Turnbuckles were bent requiring replacement of two studs. Cables were frayed slightly (loss of less than 25% of cross section) requiring installation of a preformed patch rod kit on the damaged section before Test No. 4 (see Exhibit 12-A and B).

PERFORMANCE: (See Exhibit 15). All wheels remained on the pavement throughout the run. Smooth deceleration to a 180 deg. spin-out at 200 ft. from impact. The Crosby clips were installed backwards on one cable. The cable slipped two feet during the impact (see Exhibit 11-B).



TEST NO. 4

FABRIC: None.

CABLES: Same as for Test No. 3 except 27" above the pavement (cable damaged during Test No. 3 repaired with preformed splice).

CABLE TURNBUCKLE: Same as Test No. 3, located 16 ft. and 24 ft. ahead of the point of impact.

CABLE ANCHOR: Same as for Test No. 3.

POSTS: 2¼" X 4.1# X 69" H section fence post installed with top 39" above the ground line.

POST FOOTING: Same as for Test No. 1.

PURPOSE: To test the effectiveness during collision of the shorter post and reduced cable height.

MAXIMUM ENCROACHMENT ON TRAVELLED SIDE: 17 ft.

MAXIMUM ENCROACHMENT ON OPPOSING SIDE: 17 ft.

BARRIER DAMAGE (see Exhibit 12): 27 posts were bent beyond repair, and 1 post pulled out. The preformed splice was damaged beyond repair, but there was no further damage to the cable.

PERFORMANCE (see Exhibit 16): All wheels remained on the pavement throughout the run. Smooth deceleration to a 180 deg. spin-out approximately 160 ft. from impact. The vehicle was yawing to the left when it started its spin-out and was never redirected by the barrier.

VI. REFERENCES

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Beaton, J. L., R. N. Field, and K. Moskowitz.
41st Annual Meeting of the Highway Research Board, January 1962.

2. Dynamic Full Scale Tests of Median Barriers.
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39th Annual Meeting of the Highway Research Board, January 1960.

3. Automobile to Chain Link Cable Barrier Collision.
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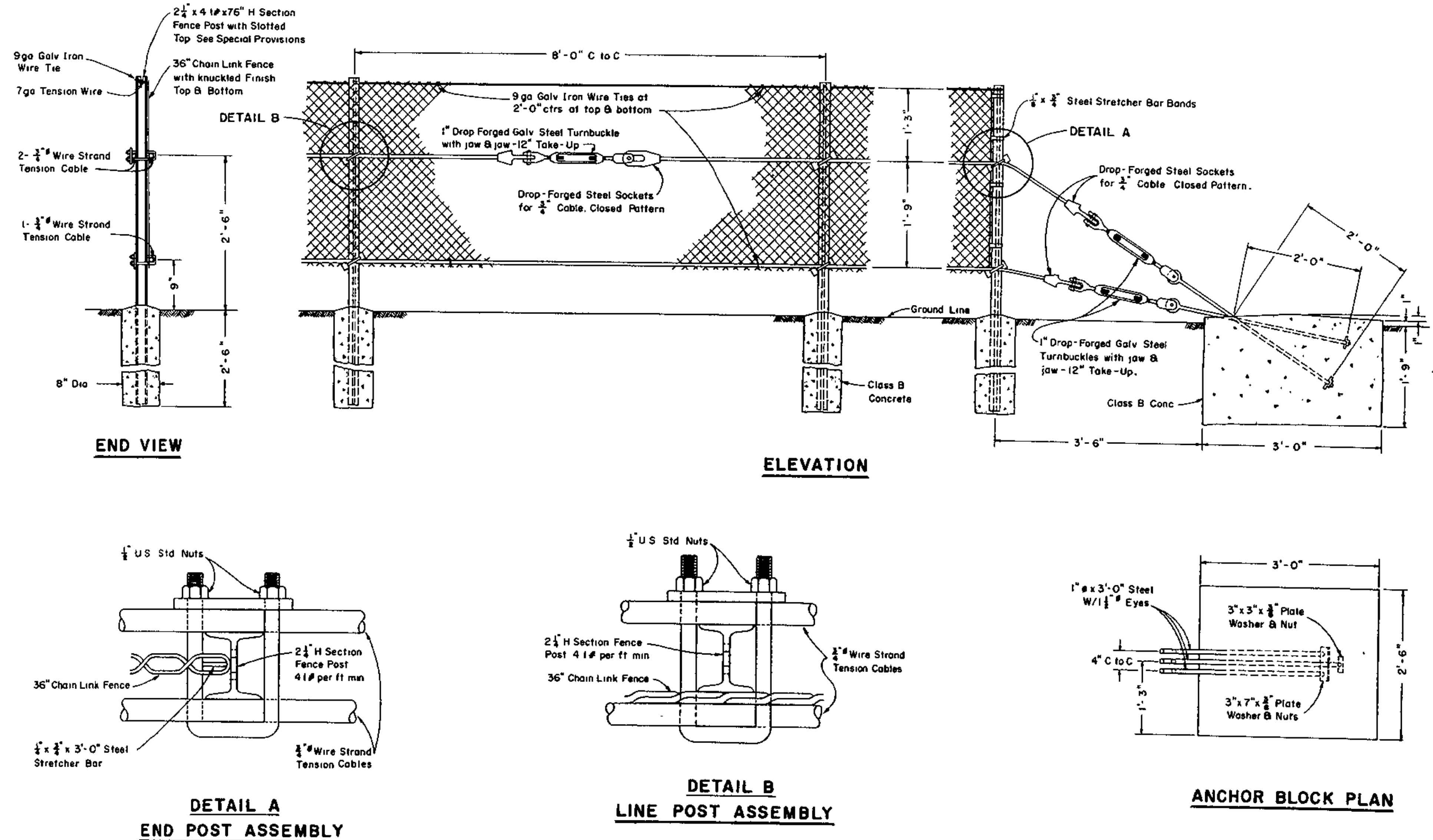
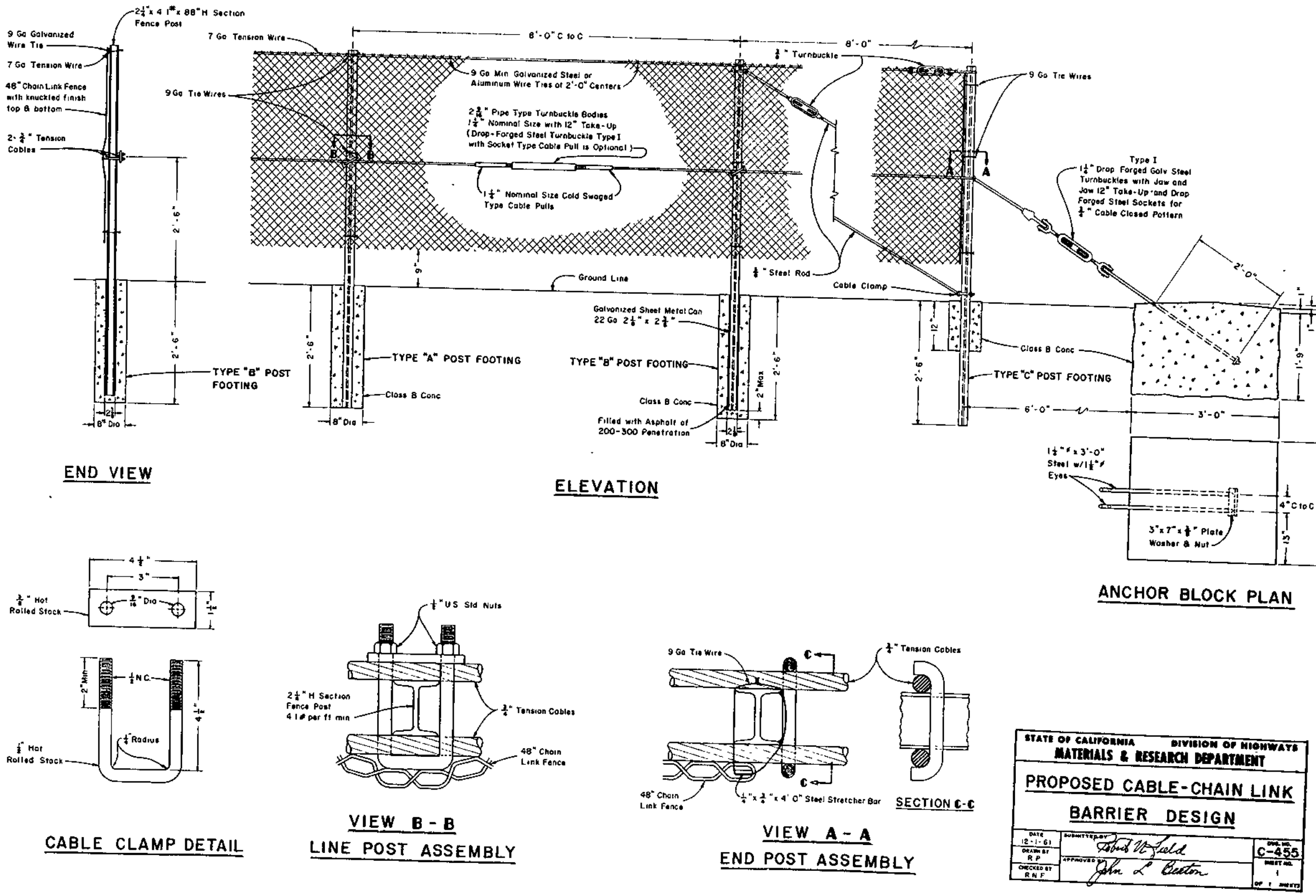
Report No. PG 12387, August 11, 1960.



CABLE-CHAIN LINK BARRIER

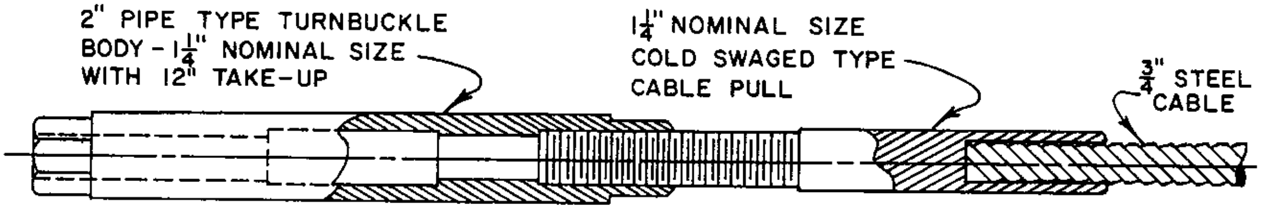
DESIGN PROPOSED IN 1959

EXHIBIT 2

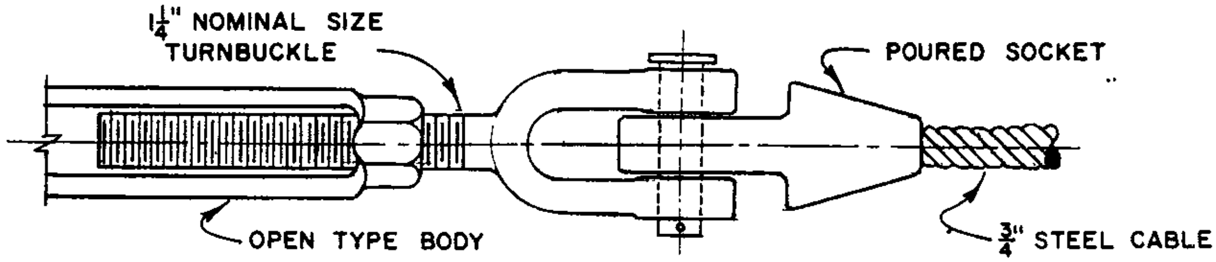


DESIGN PROPOSED IN 1961

A. PIPE TYPE TURNBUCKLE USED IN SERIES VI



B. DROP FORGED STEEL TURNBUCKLE WITH
SOCKET TYPE CABLE PULLS.



C. PIPE TYPE TURNBUCKLE USED IN SERIES VII

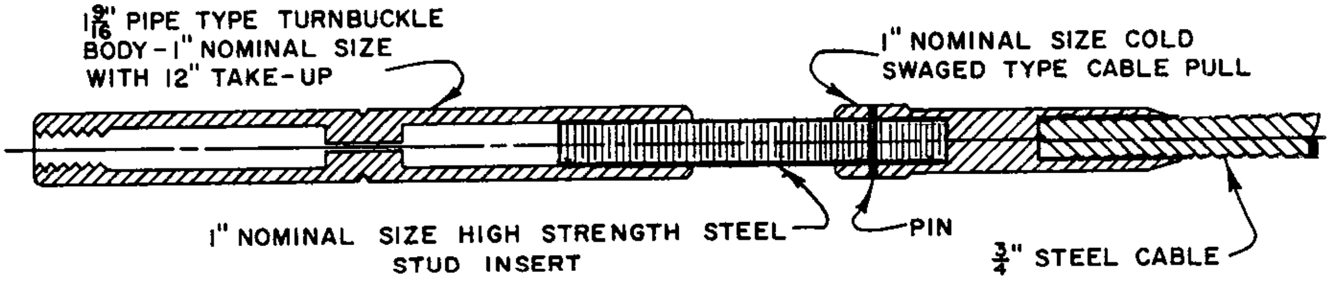
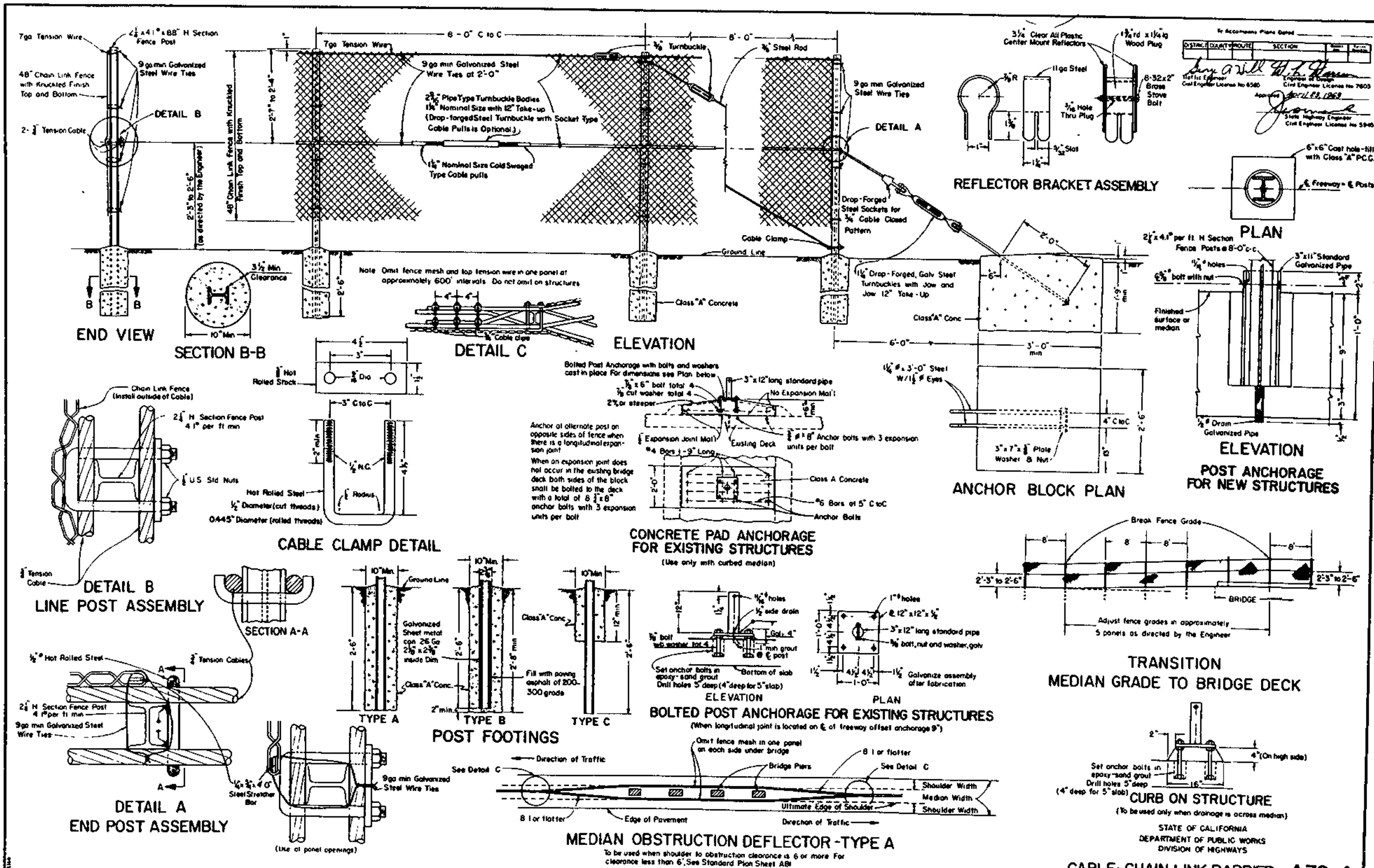
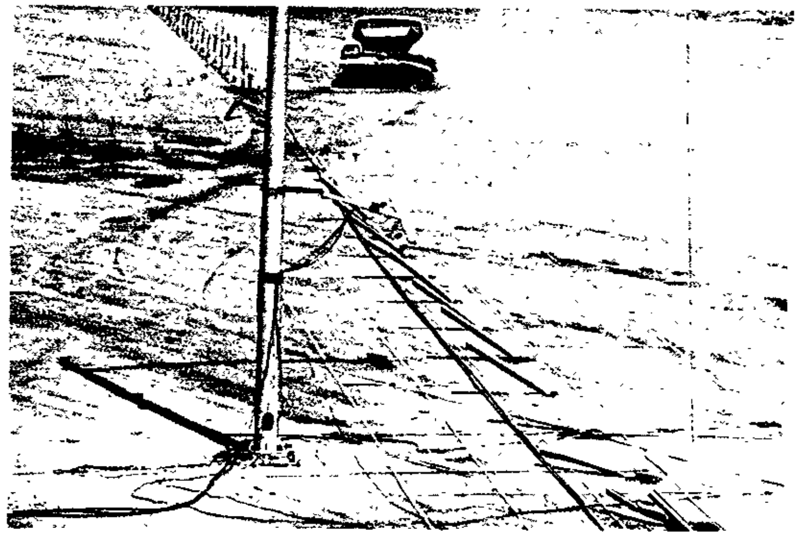
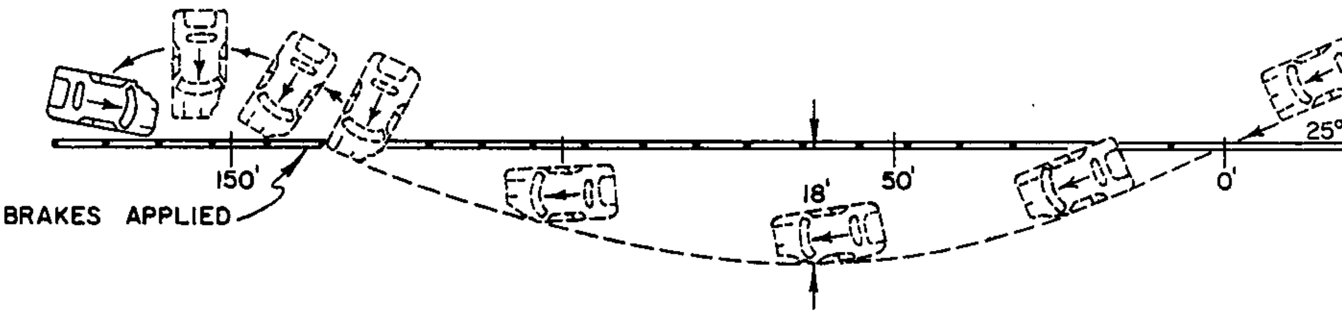


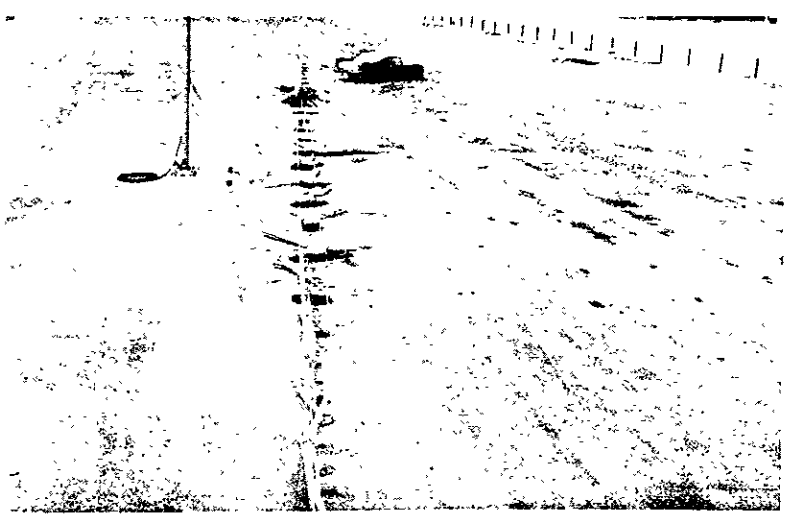
EXHIBIT 4


END VIEW
SECTION B-B
DETAIL C
ELEVATION
REFLECTOR BRACKET ASSEMBLY
PLAN
ANCHOR BLOCK PLAN
ELEVATION
POST ANCHORAGE FOR NEW STRUCTURES
CABLE CLAMP DETAIL
CONCRETE PAD ANCHORAGE FOR EXISTING STRUCTURES
(Use only with curbed median)
DETAIL B
LINE POST ASSEMBLY
SECTION A-A
TYPE A
TYPE B
TYPE C
POST FOOTINGS
BOLTED POST ANCHORAGE FOR EXISTING STRUCTURES
TRANSITION
MEDIAN GRADE TO BRIDGE DECK
DETAIL A
END POST ASSEMBLY
MEDIAN OBSTRUCTION DEFLECTOR - TYPE A
CURB ON STRUCTURE
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
CABLE-CHAIN LINK BARRIER A76-4

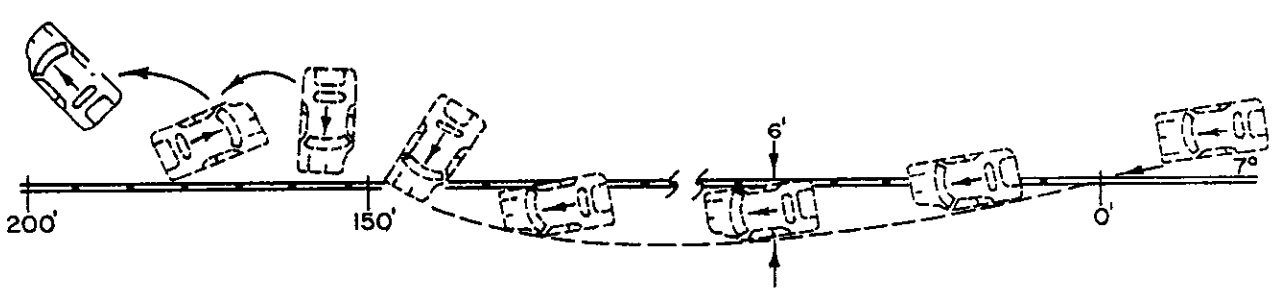


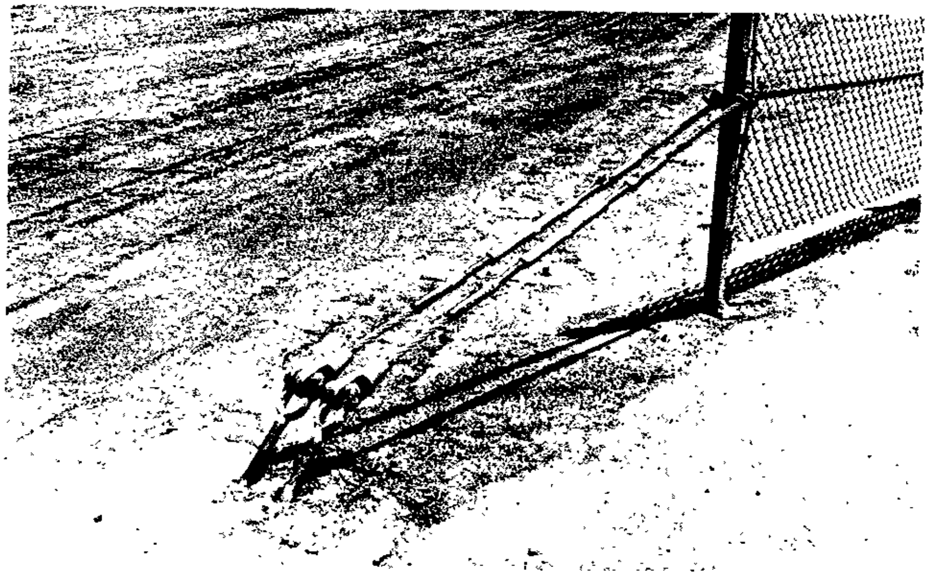
A. TEST NO. 4 – 25° at 83 MPH

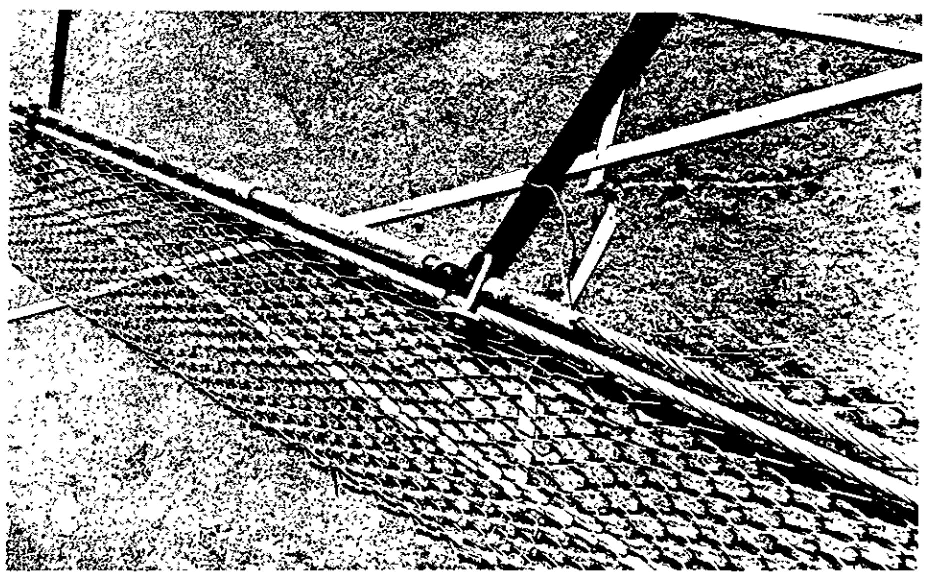


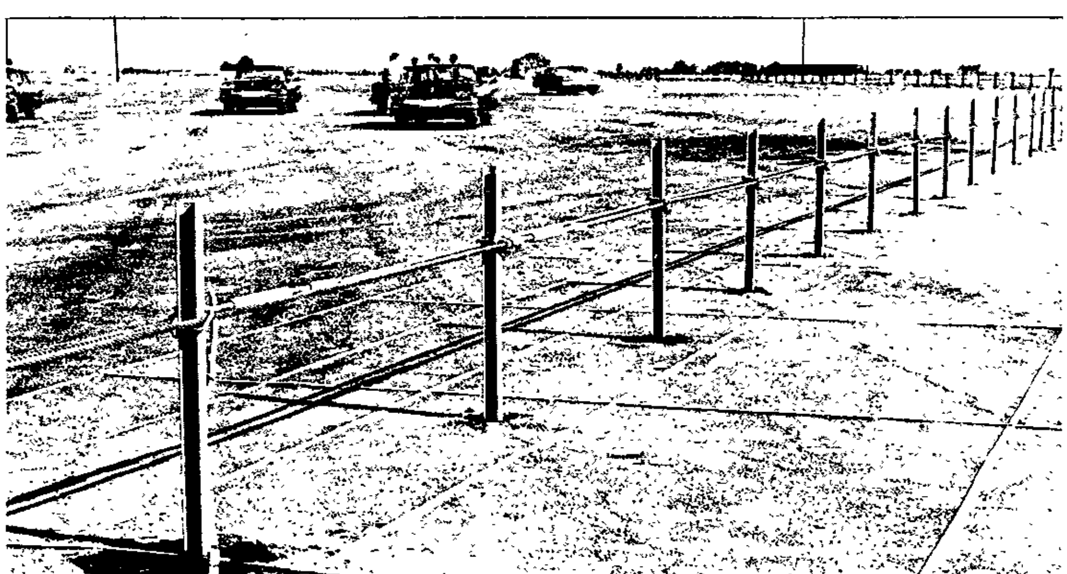


B. TEST NO. 63 – 7° at 86 MPH



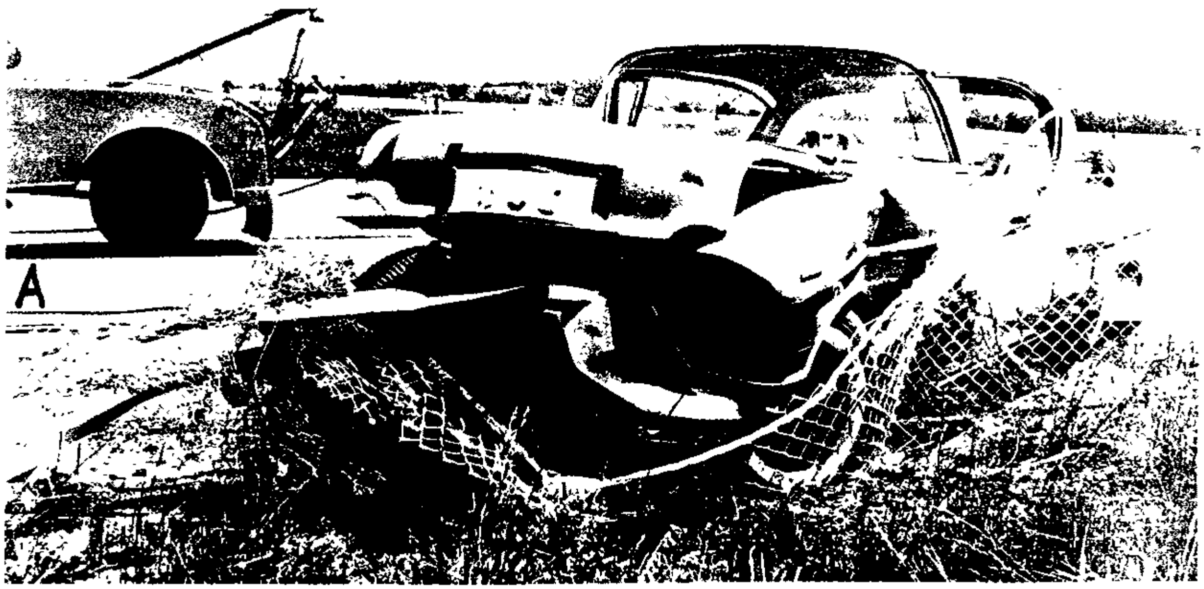






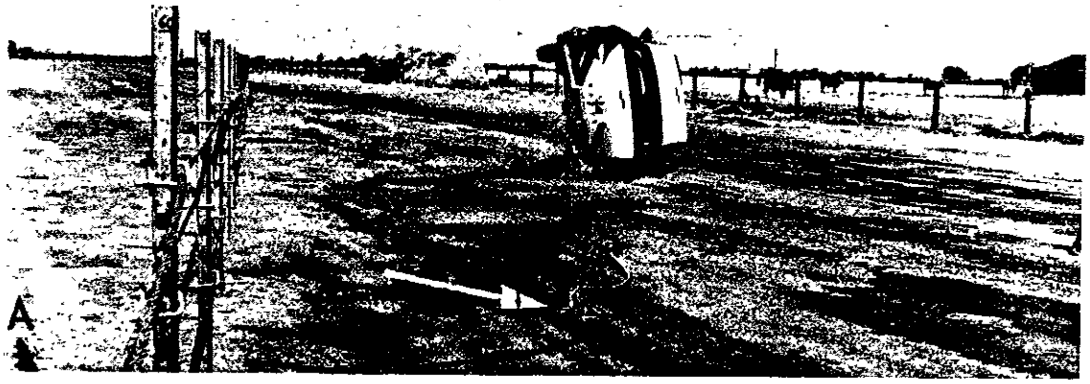
The following excerpt is from General Motors Proving Ground Report No. PG12387:

"This impact test was conducted to simulate a high-speed, very low angle type contact with the chain link-cable barrier. The barrier performed as in the previous test up to the turnbuckles in the middle of the test section. When this point was reached, the chain link fence stopped sliding along the cables and the vehicle swung around violently. The deadman on the leading end of the barrier was jerked loose and thrown 27 ft. 6 in."

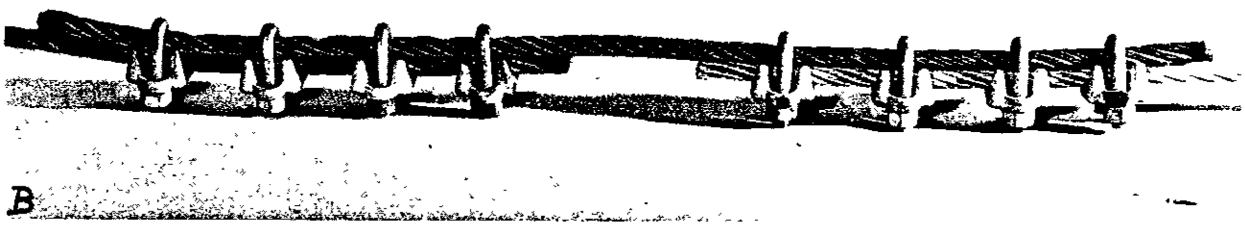


A. Vehicle Damage after 65 mph Impact.

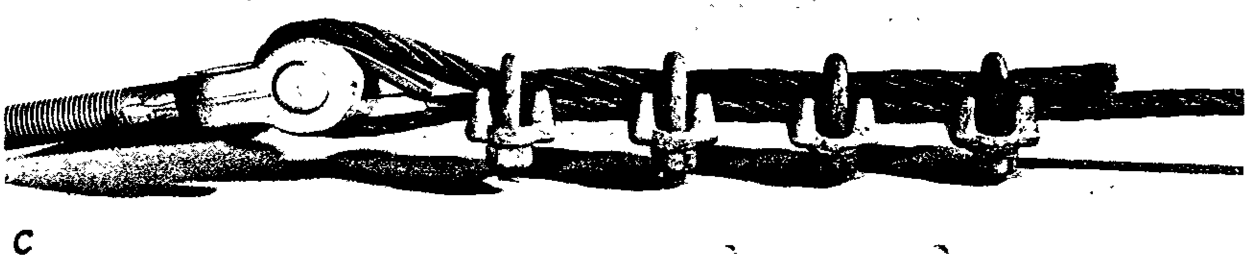
B. Close-up of Turnbuckle Trapped on Post.



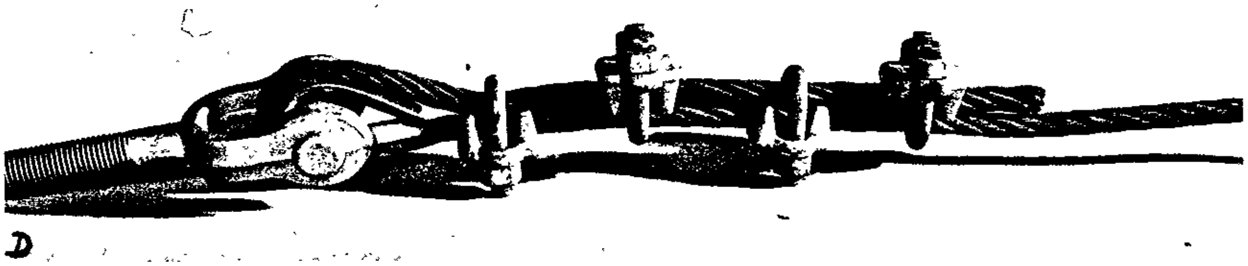
A. Failure of Preformed Splice in 1961 Test.



B. Suggested Method of Splicing.

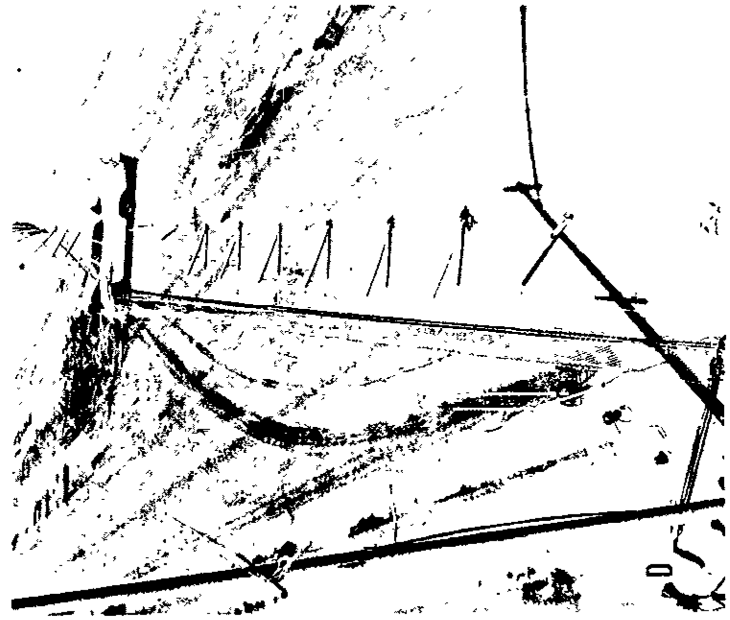


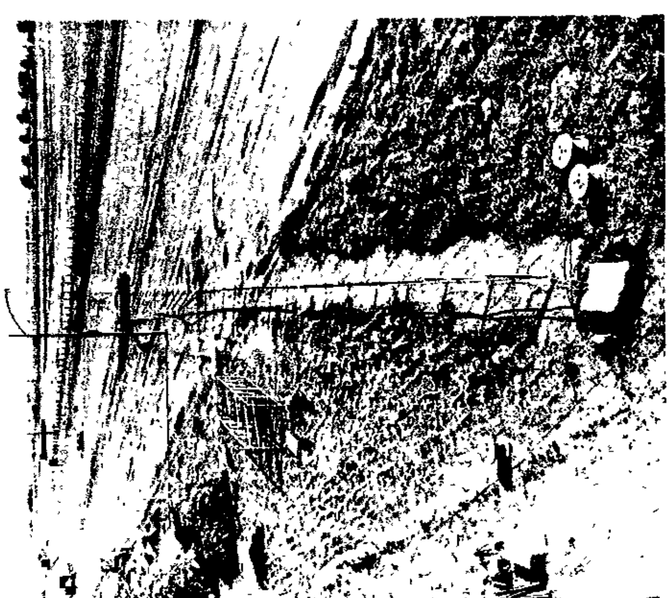
C. Proper Method of Clip Installation.



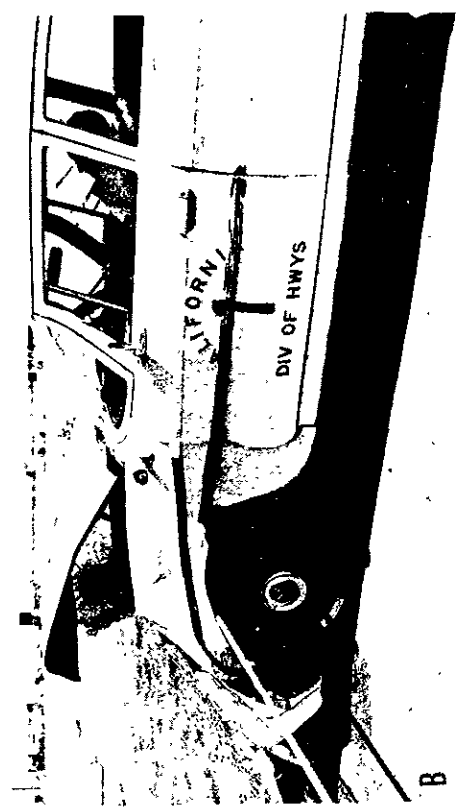
D. Improper Method of Clip Installation.

VEHICLE AND BARRIER DAMAGE



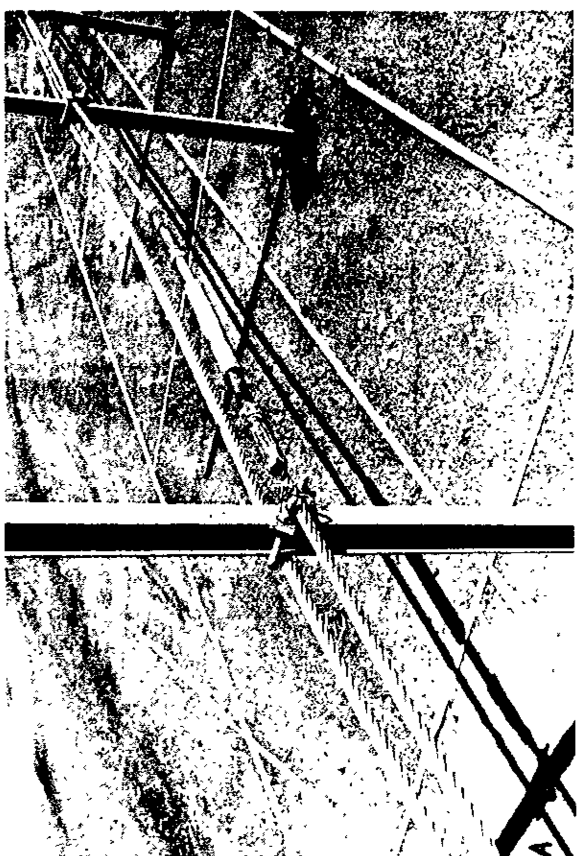


A

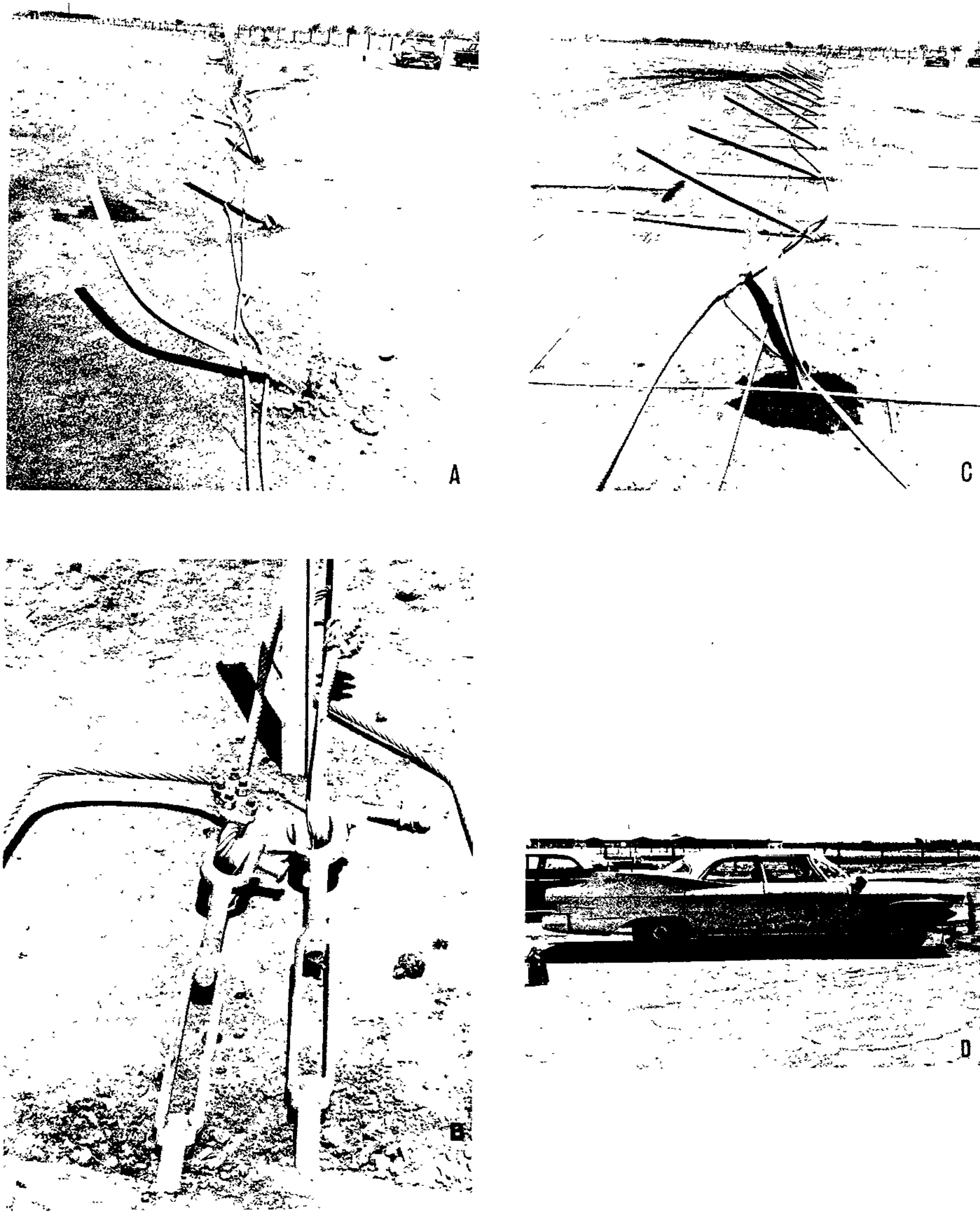


B

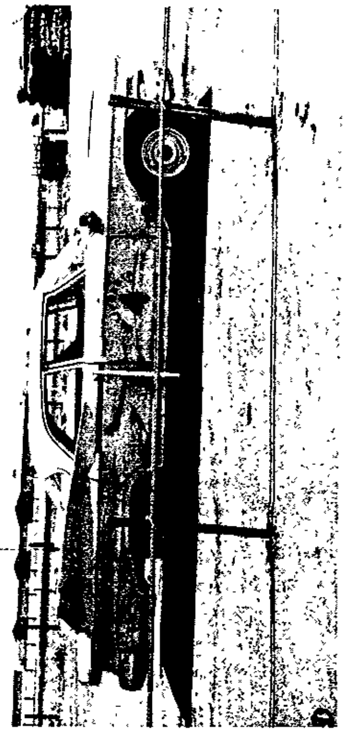
TEST NO. 2 VEHICLE AND BARRIER DAMAGE

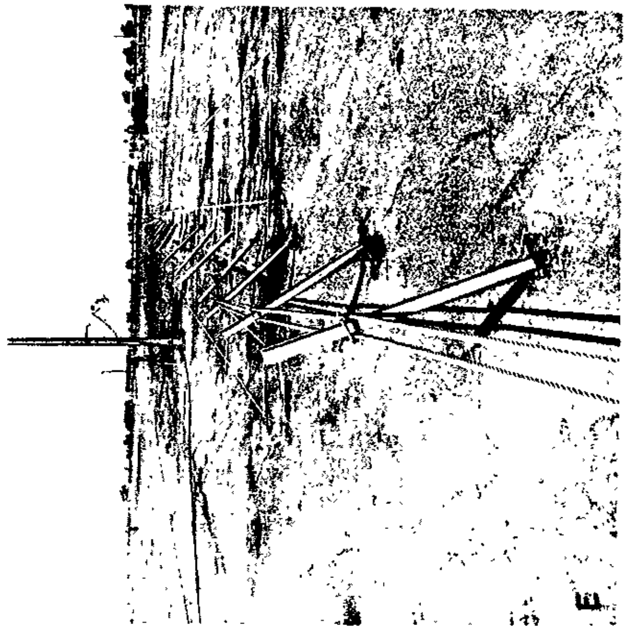


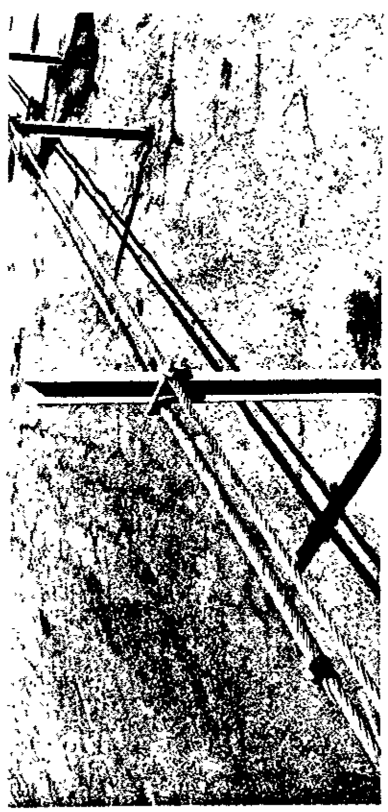
TEST NO. 3 VEHICLE AND BARRIER DAMAGE

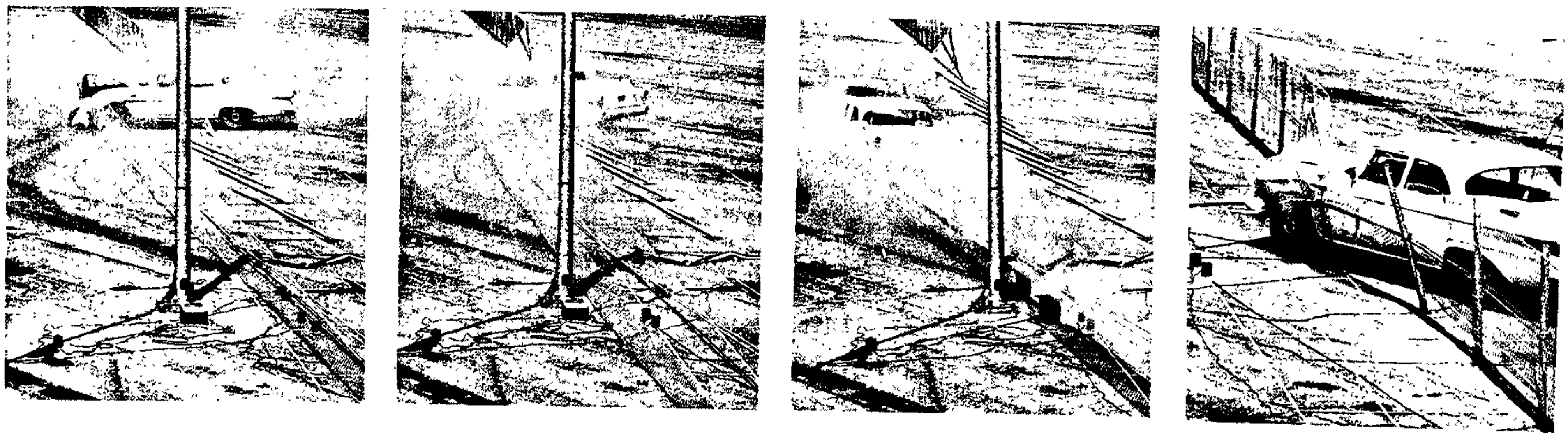


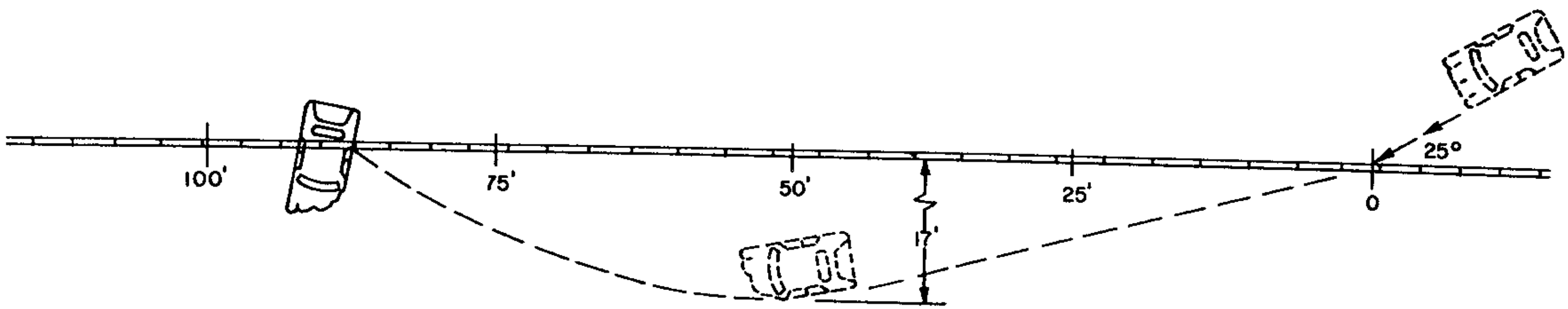
TEST NO. 4 VEHICLE AND BARRIER DAMAGE









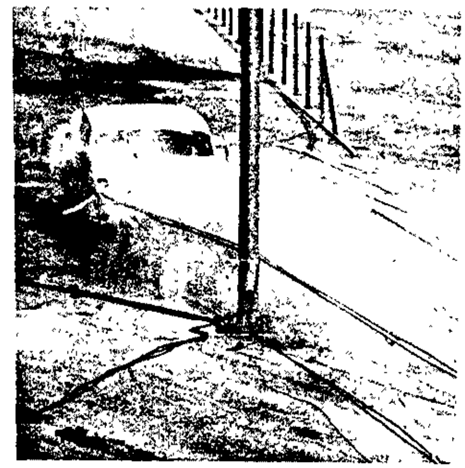


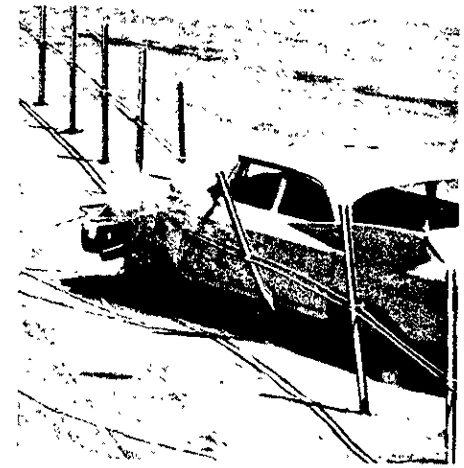
FENCE — 48" Chain link @ 9' above pvmt.)
CABLE — 3/4" 6x19 IWRC (2 @ 30" above pvmt.)
POST — 2 1/4"x4.1#x88" Stl. H Post
POST ANCHOR — Type B
POST SPACING — 8' O.C.
LENGTH OF INSTALLATION — 500'
GROUND CONDITION — Dry

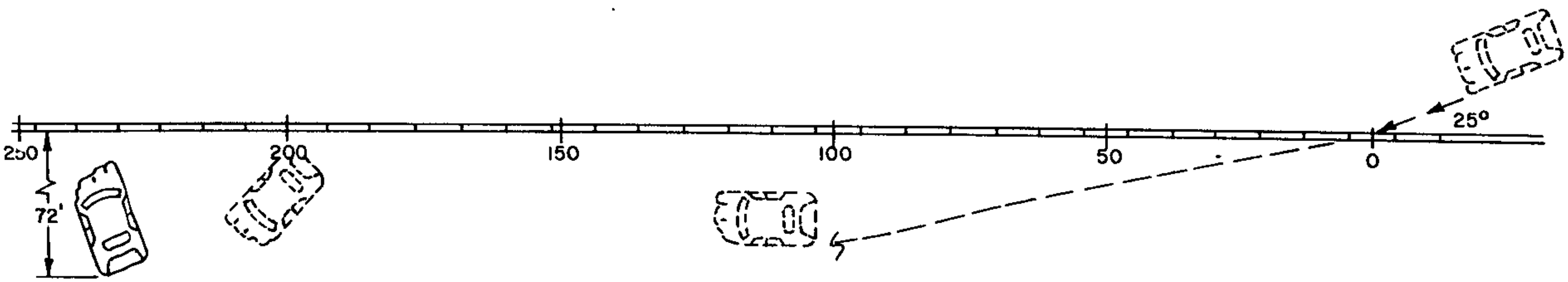
FENCE DAMAGE — 320' Anchor pulled from ground
CABLE DAMAGE — Slight fraying
POST DAMAGE — 39 posts bent-25 beyond repair
POST ANCHOR DAMAGE — 19 Cracked
MAX. DEFLECTION OF CABLES — 17'
VEHICLE DAMAGE — $600

TEST NO. — 1
DATE — 8-9-62
VEHICLE — 1960 Dodge Sedan
SPEED — 90 MPH
IMPACT ANGLE — 25°
VEHICLE WEIGHT — 4300 lbs (W/Dummy & Instrumentation)

STATE OF CALIFORNIA-DIVISION OF HIGHWAYS-MATERIALS & RESEARCH DEPT.







FENCE — No Fabric

CABLE — 3/4" 6x19 IWRC (2 @ 30" above pvmt.)

POST — 2 1/4" x 4.1# x 88" Stl. H Post

POST ANCHOR — Type B

POST SPACING — 8' O.C.

LENGTH OF INSTALLATION — 500'

GROUND CONDITION — Dry

FENCE DAMAGE — 345' Damaged-Cable anchor behind impact pulled from ground & moved 56'

CABLE DAMAGE — Slight fraying-Turnbuckles bent

POST DAMAGE — 27 posts damaged beyond repair

POST ANCHOR DAMAGE — 5 additional anchors cracked

MAX. DEFLECTION OF CABLES — 72'

VEHICLE DAMAGE — $400

TEST NO. — 2

DATE — 8-16-62

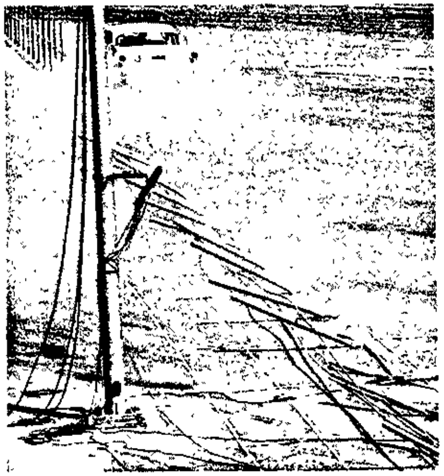
VEHICLE — 1960 Dodge Sedan

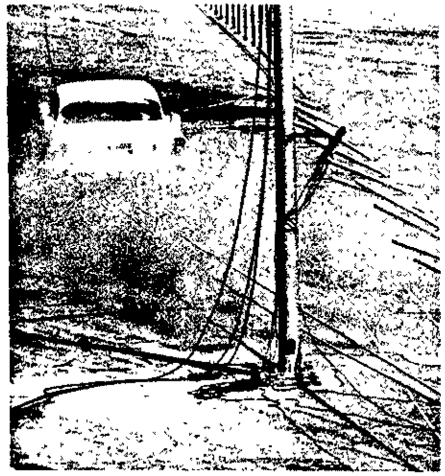
SPEED — 83 MPH

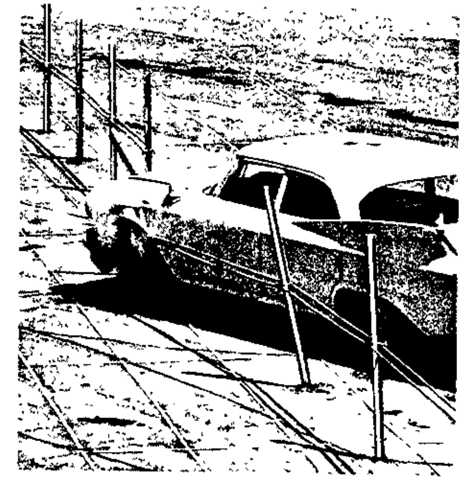
IMPACT ANGLE — 25°

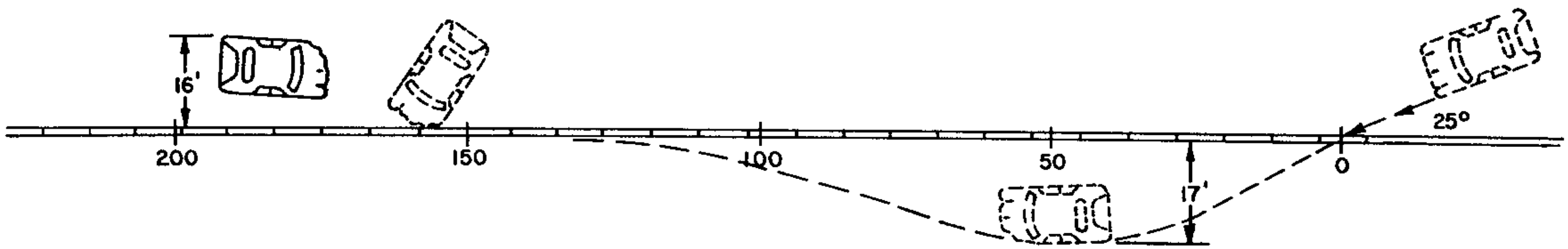
VEHICLE WEIGHT — 4300 lbs (W/Dummy & Instrumentation)

STATE OF CALIFORNIA-DIVISION OF HIGHWAYS-MATERIALS & RESEARCH DEPT.







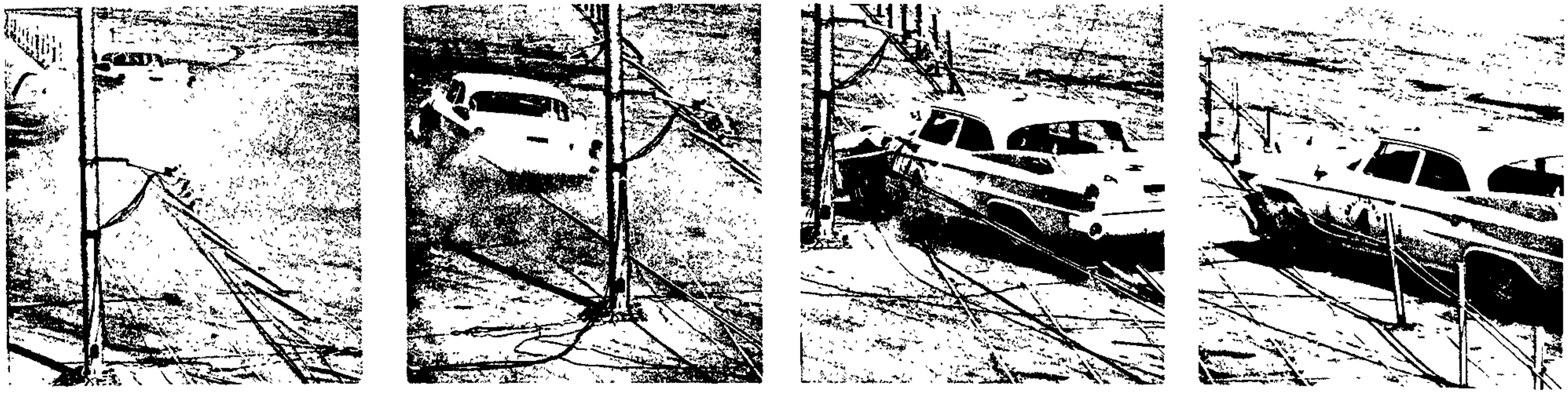


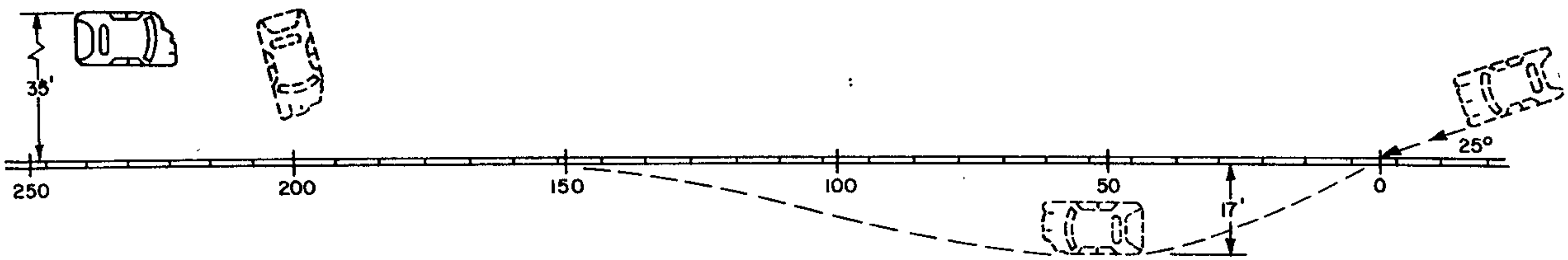
FENCE ______________No Fabric
CABLE____3/4" 6x19 IWRC (2 @ 30" above pvmt.)
POST____$2^{1}/_{4}$" x 4.1# x 88" Stl. H Post
POST ANCHOR__________Type B
POST SPACING_________8' O.C.
LENGTH OF INSTALLATION___500'
GROUND CONDITION_________Dry

FENCE DAMAGE ___________225' damaged–Cable anchor loosened but not pulled from ground–Turnbuckles bent
CABLE DAMAGE__________________Slight fraying
POST DAMAGE___________29 posts bent beyond repair
POST ANCHOR DAMAGE_________No additional damage
MAX. DEFLECTION OF CABLES _______________17'
VEHICLE DAMAGE____________________$400

TEST NO.____________3
DATE__________8-22-62
VEHICLE__1960 Dodge Sedan
SPEED__________84 MPH
IMPACT ANGLE_______25°
VEHICLE WEIGHT__4300 lbs
(W/Dummy & Instrumentation)

STATE OF CALIFORNIA–DIVISION OF HIGHWAYS–MATERIALS & RESEARCH DEPT.





FENCE ------------- No Fabric

CABLE--- 3/4" 6x19 IWRC (2 @ 27" above pvmt) Rejoined w/preformed splice

POST --- 2 1/4"x4.1# x 69" Stl. H Post

POST ANCHOR -------- Type B

POST SPACING -------- 8' O.C.

LENGTH OF INSTALLATION -- 500'

GROUND CONDITION -------- Dry

FENCE DAMAGE --------------- 216' Damaged

CABLE DAMAGE ------ No further fraying-Splice damaged beyond repair

POST DAMAGE ----------- 27 posts bent beyond repair

POST ANCHOR DAMAGE -------- No additional damage

MAX. DEFLECTION OF CABLES ------------- 17'

VEHICLE DAMAGE ------------------- $ 400

TEST NO. ------------ 4

DATE ---------- 8-30-62

VEHICLE --- 1960 Dodge Sedan

SPEED --------- 87 MPH

IMPACT ANGLE ------- 25°

VEHICLE WEIGHT - 4300 lbs (W/Dummy & Instrumentation)

STATE OF CALIFORNIA-DIVISION OF HIGHWAYS-MATERIALS & RESEARCH DEPT.